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Recommendations for an undergraduate program in food sciences are made. Several assumptions are made with regard to food science graduates of 20 years hence: (1) high school graduates will have backgrounds in chemistry, biology, and mathematics comparable to present day college sophomores; (2) the scientific framework for education in food science must focus on basic disciplines of production, processing, and consumption of goods; (3) courses in food science and technology will continue to be a necessary part of the undergraduate program; (4) it is recognized that biology, chemistry, physics, and mathematics are undergoing radical revisions in educational approach; and (5) the undergraduate curriculum is a flexible one, subject to constant modification. Recommendations are made for the biological and physical sciences and mathematics aspects of the program. A core program in biology is presented in the appendix. (BC)

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Report of the

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FOREWARD

In 1965 the Commission on Undergraduate Education in the Biological Sciences (CUEBS) established a Panel on Preprofessional Training in the Agricultural Sciences (PPTAS) to consider the following questions:

(1) What preparation in basic biology, physical sciences and mathematics is desirable for students planning careers in the agricultural sciences?

(2) To what extent can agricultural curricula include the same biology core program taken by other biological science majors?

The panel early recognized that it would be an Herculean task to evaluate adequately all the implications involved in the questions posed, especially when students in such divergent areas (e.g., forestry, wildlife, food science, agricultural engineering, preveterinary medicine) were to be considered. In an effort to obtain the broadest thinking possible, six action committees composed of scientists from universities throughout the country were created in cooperation with the Commission on Education in Agriculture and Natural Resources (CEANAR). Each action committee considered one of the following areas: animal sciences, plant and soil sciences, natural resources, food sciences, bioengineering, social sciences; and each was charged with the responsibility for studying and recommending desirable preparation in the biological sciences and cognate disciplines for undergraduates majoring in the committee's area of specialization. The committees were asked to think in terms of requirements for students who will be professional scientists and agricultural production workers in the 1980's.

The following report is from one of the action committees. The ideas expressed in the report are those of the action committee members and not necessarily those of either of the sponsoring Commissions. The PPTAS position paper itself is available as CUEBS Publication No. 17.

Martin W. Schein
Director, CUEBS

INTRODUCTION

Food as a basic need of mankind has been the prime tool in shaping civilization from the very beginning. Thus, the progress of a nation is directly related to its ability to accumulate, store and distribute foodstuffs at costs which permit its members to to meet their biological and cultural needs for food. It has been calculated that over 3×10^{12} kilograms of food are consumed by humans annually and the world's population is constantly on the increase.

Cultural developments have made food susceptible to religious and social scrutiny; its possession can be a status symbol, power and object to envy; its need can be fatal. Rising standards of living in many parts of the world today, increased sophistication of various food industries, coupled with the need to supply and preserve food for underdeveloped countries requires expanded scientific effort to yield the necessary knowledge in food science to meet the ever increasing demands of mankind. The effort must be interdisciplinary. The fact that food science is interdisciplinary necessitates that undergraduate education should provide the food scientist with sufficient knowledge to 1) understand the technical and economic aspects related to securing, processing, preserving and distributing food, 2) be able to communicate technically with chemists, biologists, mathematicians, physicists and engineers as well as with the masses of people for whom the products of his efforts provide sustenance.

Besides the requirement for increasing food supply there is the problem of coping with the rapidly expanding wealth of new knowledge. With the advancement of knowledge, food scientists have produced and will continue to produce new food forms and sources. For example, the new food sources will include microbially derived food from petroleum and what are now considered industrial wastes, chemically synthesized amino acids, algae, plant protein isolates and fish flours.

Within the present generation these innovations in the production and processing of foods appear likely to accomplish significant improvements in both the quality and cost of many foods.

Those who are concerned with the growing food deficit for most of the world's population, however, will recognize that for economic and cultural reasons these new products have little potentiality for contributing to the food needs of the world's peasantry. Ninety percent of the population of most emerging nations lives completely outside commerical food channels and therefore, has no access to processed foods. These people present a second challenge to the food scientist of coming generations--the adaptation of current food knowledge to the emerging nations.

It is necessary that the food scientist be firmly grounded in the basic sciences and be able to apply his scientific learning to the problems. He must also appreciate fully the implications of new knowledge and apply it properly in the solution of the world's food problems.

Before developing, as best we can at this time, the most desirable undergraduate program, certain assumptions and premises must be made regarding the function of the food science graduate in the future--say two decades from now.

First, the assumption has been made that the high school graduate 15 years from now will have educational background in chemistry, biology and mathematics comparable with students currently entering their sophomore year in college.

Second, the development of an undergraduate scientific framework for education in food science needs to focus attention on those of the basic disciplines which provide the fundamentals on which the production, processing, and consumptions of foods is and will be based. Regardless of whether the food science graduate follows a commerical, governmental or academic career he is destined for premature obsolescence if his educational base consists largely of information on current food practices. Coversely, if the content of his formal education provides him with a mastery of the basic sciences on which commercial processes are or will be based, as well as food science courses to properly orient his knowledge, he has the tools for development of better ways of handling foods and clearer understanding of the potentialities of innovations in the field as they appear. For the graduate B.S. such training will further increase the number of possible employers in a broad spectrum of food industries. For the student continuing his formal education to a higher degree this background should be a strong base upon which he may add training and research experience that will qualify him professionally as a food scientist. For both types of students this basic background permits the teaching of food science courses at a meaningful level further minimizing the chance for obsolescence.

Third, courses in food science and technology <u>per se</u> continue to be a needed part of undergraduate offerings. Such courses, founded on the basic sciences, would be taken normally in an undergraduate's junior and senior years. Orientation to the principles, practices and problems in the food field <u>are still essential</u> in the training of a food scientist if he is to properly evaluate the problems he will face in his future career.

Fourth, in consideration of the food science undergraduate framework, it is necessary to recognize that biology, chemistry, mathematics and physics are currently undergoing radical revisions in approach. For example, biology, which has been primarily descriptive for many decades, is being replaced with a "new biology" in which analytical and quantitative treatments are making a dramatic impact.

Fifth and last, an undergraduate curriculum constitutes not a fixed but rather, a flexible guideline subject to constant modification, revision and alteration. It should also be recognized for the food scientist that the knowledge gleaned in his study of the basic sciences is a prerequisite base, not an ultimate end for his training.

It is quite evident that the mathematical, chemical and biological concepts which are included in these outlines are interdependent. In the practical design of courses close attention will have to be given to the sequence in which subjects are offered. Without such attention to this matter of scheduling the interdisciplinary impact which is intended will be lost. The committee has examined the practicality of sequencing the mathematics, chemistry and biology courses and has found not one but several ways of arriving at logical sequences and recommends that specific scheduling be developed by each institution taking cognizance of local conditions.

In recommending a program of study it was envisioned that food industries of tomorrow will need technologists trained to the professional level equivalent of a B.S. and/or M.S. degree and scientists trained to at least the Ph.D. level. Although primary consideration has been given to those students planning to continue on to graduate study, the basic core program proposed here is suitable for both groups of students.

The committee members are in general agreement with the broad outlines set forth in this report. None of the proposed courses should ever be considered as fixed standards but, rather, as flexible guidelines subject to constant revision. By the same standards "core" curricula should be temporary structures. Efforts by all concerned in the education of students--at all levels--will result in gradual improvement of courses and curricula only if the "ultimate" is sought--not assumed to be attained!

BIOLOGICAL SCIENCES

Basic Biology

As a point of departure in Committee deliberations, the "biological core" of curriculum "Betty" as outlined in CUEBS Publication No. 9, April 1965, was used. (See Appendix A) Concensus showed that this curriculum was quite adequate--but not optimal as it was felt to contain a certain amount of material "irrelevant" for a food science major. In the basic biology program material should be taught on a functional level rather than upon taxonomic bases. Mastery of the chemical aspects of biochemistry should be prerequisite to the study of the metabolic portion of the program.

With these things in mind, it is recommended that the following topics be included:

1. Molecular topics, stressing function and structure at subcellular levels and including enzyme synthesis and regulation and metabolic pathways.
2. Cellular biology, including the cellular basis of life, organization and structure of cells and cell division.

3. Organismic biology, including development of uni- and multi- cellular organisms; correlative mechanisms in the regulation of growth and form; environmental adaptations; periodicities and rhythms; nervous systems and behavior, absorption and translocation of water, minerals, etc.

4. Structure and dynamics of ecological systems (population and community), including properties of populations; biotic communities (nutrient cycling and energy transfer, homeostatic processes); population genetics (evolutionary mechanisms and systematics) and ecological aspects of natural selection.

5. Genetics and its potentials, including instruction in classification, phylogeny, evolution, etc.

In addition to a basic biology program, three biological science courses are considered necessary components of a food science and technology undergraduate curriculum. These are 1) Microbiology, 2) Physiology and Nutrition; and 3) the physical properties and behavior of biological materials.

Microbiology

Microbiology warrants special emphasis because of its importance in food preservation, sanitation, spoilage and public health. Further because of the strong likelihood of future foods being derived from all kinds of living cellular sources, the usual preoccupation in treating microbiology as bacteriology should be avoided. Rather, instruction should include study of the many microscopic plant and animal taxa. The following topics should be included:

The Science of Microbiology
Cell Structure
Physiology
Immunological Microbiology
Heredity of Microorganisms
Ecological Relationships (populations)

Of these topics it was felt that less emphasis could be placed on "immunological microbiology" and "heredity of microorganisms" while greater stress be placed on "physiology" and "ecological relationships." This course should form a foundation for subsequent instruction in food microbiology.

Physiology and Nutrition

The contents of this course should stress nutrient quality availability and acceptability of foods. Areas to be included for study are as follows:

Theoretical comparative nutrition (nutrilites, availability and balance of nutrients)
Principles of dietetics
Principles of pharmacology (antimetabolites, toxins, poisons, detoxification)
Nutritional physiology (appetite control systems, comparative digestive physiology, taste and smell, etc.)
Man as an ecosystem and as a component in the world ecosystem.

The Physical Properties and Behavior of Biological Materials

Biological materials are unique in their complexities; hence, special treatment of their properties and behavior is needed. Instruction should include these areas:

Fluid Behavior (viscosity, surface tension, plasticity and elasticity)
Solid Behavior (tensile strength, yield, compressive strength)
Polyphasic Systems (suspensions, solutions, gels, foams, emulsions)
Electrolytes
Interfacial Phenomena (surface activity, films, absorption)
Membranes
Energy Transfer (heat conductivity and heat capacity, electromagnetic radiation, transmission, reflection and absorption refraction and defraction)
Anisotrophy

PHYSICAL SCIENCES AND MATHEMATICS

Chemistry, physics and mathematics are necssary prerequisites as well as formative bases for the biological sciences pertinent to the education of the food science major.

Mathematics

The mathematical training of the food science major should prepare him to analyze changing and random phenomena. Further, he should be able to solve to a limited extent the mathematical expressions developed in his analysis by the techniques of calculus and numerical methods with the aid of computers. In order to deal with large sets of equations in more than two dimensional systems, he should have some familiarity with matrices and vector spaces. The instruction should be such that the student will be familir not only with the mechanics of mathematical manipulations, but also with the working possibilities of the subject matter. Examples should be drawn from the biological as well as the physical sciences.

It is envisioned that the instruction necessary to accomplish this training should be courses in calculus, mathematical analysis, linear algebra and probability.

It is expected that further mathematical training will occur in the upper-division courses through the application of statistics and mathematical analysis in these courses.

Physics

A course in physics should provide a base for understanding and interpreting physical phenomena. Topics for instruction would include mechanics, introduction to heat, mass and momentum transfer, electromagnetic fields and radiation. Assuming that high school physics will include the properties of heat, light, sound, etc. in the traditional sense, the college physics could then be based on a level of understanding employing calculus and consequently would normally be a sophomore year course.

Chemistry

The proposed chemistry would not be taught in the traditional manner but rather as a program which would focus attention on the common denominators among the usual sub-divisions of chemistry. Course contents would include the following: atomic structures and reactions, molecular structures and reactions (this area to include thorough treatment of the chemical aspects of biochemistry including polymers), reaction mechanisms, qualitative and quantitative analytics (emphasizing instrumental analyses), equilibria, kinetics, thermodynamics-energetics, quantum and statistical mechanics, surface and catalytic pehnomena and photo-chemistry. It is assumed that additional courses (particularly organic, physical and biochemistry) will be taken by the prospective graduate students.

As mentioned previously, the chemical aspects of biochemistry should be completed prior to the discussion of metabolic biochemistry in the biological course program.

Additional instruction of upper-division standing preceeded by the proposed chemistry is recommended. This instruction would be specifically directed to foods and their complexities. Emphasis would be on the chemistry of basic food components, on flavor, appearance and changes occurring when foods are processed, transported and stored.

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APPENDIX A

THE BIOLOGY CORE - "CURRICULUM BETTY"

The content of the core should include material from each of the following seven areas of biology. No area should be entirely neglected, but the amount of time spent on each area may vary according to the kind of core-structure adopted and the particular bias of the staff or institution. The sequential listing of these areas is not meant to imply an order for teaching purposes; the latter must be determined according to the decisions reached on core-structure. The following content is derived partly from the deliberations of earlier conferences (see NAS-NRC Publication 578 and Bioscience 14(8): 25-29, 1964).

1. Molecular Topics. Elementary biochemistry; nucleic acid structures and functions; protein structure, synthesis and regulation; properties of enzymes; biochemical synthetic pathways and energy metabolism.

2. Cellular Biology. Cell structure and function; gross and fine structure, principles of molecular aggregation, physico-chemical organization of cells; energetics, transport, mobility, irritability and homeostatic mechanisms. Cell growth and cell division. Cell differentiation and transformations; clonal variation and development. Evolutionary potential of cells: protistan evolution, origin and multicellularity.

3. Genetics. Mendelism - historical aspects: discovery and rediscovery of laws and modifications, linkage. Cytological basis of inheritance: meiosis, mitosis, nondisjunction. Molecular genetics: physical basis of the gene; gene action and regulation: homeostasis, integration in steady-state. Cytoplasmic inheritance; genes and development. Mutation: chromosomal aberration, effects of radiation. Genes in populations: evolution (speciation).

4. Development. Plant and animal ontogeny (molecular to gross structural levels); experimental investigation of plant and animal development. Problems: aggregation (molecular, cellular, multicellular). Directive aspects (induction, regulation differentiation). Evolutionary aspects.

5. Organismic Biology. Structural and functional organization of selected higher plants and animals; a modern synthesis including 1) facts about the complications of organization of higher organisms, and 2) contemporary heuristic topics such as biological clocks, photo-induction of flowering, electrophysiology, neurosecretio immune and self-recognition mechanisms, behavior.

6. Population and Community. Structure and dynamics. Environmental action and internal reactions; symbioses and competition. Behavioral and developmental aspects of adaptation. Energy flow, homeostasis and succession. Ecological aspects of natural selection.

7. Evolution and other over-all concepts. Present as recurrent themes in each of the preceding areas, but may receive independent, synthetic treatment as well. In addition to evolution, there are historical perspectives, techniques and metho of science, applications and contributions of biological science to man's intellectual life and culture, and aesthetic aspects.

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